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955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

B71 06034

date: June 21, 1971

to: Distribution

from: C. Bendersky

subject: Further Comments - Hard Ice Formation on a Heak Sink Booster - Case 237

ABSTRACT

Additional information on the problem of hard ice formation on the cryogenic tankage of heat sink boosters is reviewed. The data affirm the probability of hard ice formation on uninsulated tankage. Indications are that film type coatings such as Teflon could substantially reduce the thickness of hard ice which could adhere to aluminum cryogenic tankage.

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MEMORANDUM FOR FILE

The problem of hard ice formation on heat sink boosters was reviewed in Reference 1. It was concluded therein that the problem was real; that hard ice formation on a heat sink wall during rainstorms could seriously compromise the concept in that accumulation of ice might preclude launching during rainstorms due either to weight penalty or damage if the ice were to break loose. The topic has been further researched, primarily with the help of Major J. Bryant of the Standard Launch Vehicles Program Office, SAMSO, and the McDonnell Douglas Astronautics Company-West (MDAC-W). This memo discusses the additional information.

DISCUSSION

Major Bryant searched the Air Force and MDAC Thor Project records on the subject. The most significant piece of information obtained related to a 1965 Thor launched GEOS A. This Thor LO_2 tank was exposed to rain for 64 minutes between the start of LO_2 loading and liftoff. This ice was shed upon engine start whereupon the Thor flight performance was within specifications. The results of a worst case analysis of the potential hard ice buildup indicated that as much as 3000 lbs could have been attached to the LO_2 tank. It was concluded at that time that no evaluation of the effects of this added weight on either vehicle performance or launch pad damage could be made. At present the MDAC-W Thor/Agena and Thor/Delta Program Offices essentially ignore the subject. (Major Bryant noted that the above also applies to SAMSO Atlas vehicles.) Thus ice formation has not been a problem in Air Force launches of Thor or Atlas vehicles.

MDAC-W independently has researched the subject. A bibliography of the literature obtained is appended. Figure 1 summarizes the total data available while Figure 2 presents detail data from 21 Thor booster flights. The data shown in both figures repeat and confirm the observations made in Reference 1, namely that during rain, heavy ice does form on uninsulated LO_2 or LN_2 tanks. In fact, the records for Boosters 136 and 202 as reported in Figure 2 indicate that ice formed on high humidity non-rainy days. However, MDAC-W chose to question these particular data points. In 1968, MDAC conducted icing tests on aluminum tanks uncoated or coated with selected polymer films. The results (Figure 3) show that tank coatings such as Teflon can substantially reduce the shear stress at which ice will shed from an aluminum tank, thus reducing the thickness of ice buildup. MDAC-W stated that for proper heat sink booster design it would be necessary to (1) determine the shear and tensile bond strength of ice on coated and uncoated aluminum tankage, (2) determine the areas of a vehicle which will require protection from falling ice, and (3) assess the potential vehicle performance degradation. MDAC-W is presently studying experimental approaches which could provide the desired design data.

MDAC-W has been working on a heat sink booster concept whose features have less potential ice problems than the Grumman concept described in Reference 1. The Grumman booster separates at a velocity of 8450 ft/sec and requires that the internally insulated LH_2 tank wall temperature be colder than -250°F at liftoff. The MDAC-W booster separates at a velocity of 7677 ft/sec. This lower velocity significantly reduces the thermal input to the booster structure during flight and allows internally insulated LH_2 tank wall to be designed to be at ambient conditions (+70°F) at liftoff. The extra internal insulation required to maintain the larger temperature difference between the aluminum tank and the LH_2 propellant does not penalize the vehicle performance. (Both the Grumman and MDAC-W designs use the same criteria for the uninsulated LO_2 tanks.) No ice should be formed on the +70°F tank walls. Ice will form on the LO_2 tanks. MDAC-W believes that film coatings applied to the LO_2 tank will substantially reduce the ice thickness and hence the damage potential.

MDAC-W also believes that coatings such as Teflon can have adherence lifetimes which will not reduce the booster overhaul time. In essence, MDAC-W does not feel tank icing is an important selection criteria in consideration of their heat sink booster concept.

COMMENTS

The MDAC-W heat sink booster design compared to the Grumman approach, if feasible, would reduce the damage potential of hard ice fall-off during liftoff. However, the potential for damage still is present. It would appear in order to conduct an experimental test program to provide data to better define the hard ice damage potential and possible means of preventing this damage.

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Attachments
Figure 1-3
Bibliography

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6. "ICE AND FROST FORMATION ON LOX TANK DURING GEOS A LAUNCH OPERATIONS IN INCLEMENT WEATHER," McDONNELL DOUGLAS MEMORANDUM A2-260-AAAS-05662, DATED DECEMBER 1965
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SOURCE: MDAC-W

ICE DATA SUMMARY

VEHICLE OR TEST	TEST CONDITIONS	SURFACE TEMPERATURE	SUMMARY OF RESULTS
THOR	GROUND HOLD AT KSC UNINSULATED LOX TANK	–290°F	DATA FROM 21 THOR BOOSTER FLIGHTS SHOW ICE & FROST WEIGHT FROM 0 TO 2.64 LB/FT^2
SATURN	S-IVB STAGE STATIC TEST AND 8-FT DIAMETER TANK AT SACREMENTO	INSULATED LH_2 TANK 75°F NO ICE/FROST –250°F WITH ICE	S-IV-10 LH_2 TANK LIFT-OFF TEMP = 75°F S-IVB STAGE AND 8-FT TANK TEMP –250°F WITH ICE 0.5 LB/FT^2
JUPITER/JUNO	8 – 10 HOURS OF HOLD IN LIGHT RAIN	–290°F (LOX)	300 LB (0.6 LB/FT^2) OF ICE AND SNOW – CAME OFF AT LAUNCH
A. D. LITTLE TESTS	SIMULATED RAIN ON LN_2 TANK	–320° (LN_2)	20 LB/FT^2 OF ICE-DETACHED UNDER ITS OWN WEIGHT. LOW DENSITY LAYER NEXT TO SURFACE
SAVINO AND SIEGEL	FLOWING LIQUID OVER COLD SURFACE	–20°F TO 32°F	AT INITIATION OF FLOW LOW DENSITY, LOW CONDUCTIVITY ICE FORMED

SOURCE: MDAC-W

FIGURE 1

BOOSTER	BAROMETRIC PRESSURE	AMBIENT AIR TEMP.	WIND VELOCITY	RELATIVE HUMIDITY	CONDITIONS	ICE OBSERVATIONS	WEIGHT – LBS DM-18	DSV-2L	REMARKS
104	30.145	78.2°F	12 MPH	90%		1/2" FROST & 1/32 ICE UNDERCOAT	96	135	18 LBS FROST 78 ICE
105	30.25	80.5		90%		5/8" FROST & 1/16 ICE UNDERCOAT	130	254	23 LBS FROST 157 ICE
107	29.875	75.3		94%	DRIZZLING	3/8" CLEAR ICE	944	1332	
108	29.86	77.5		86%		1/2" FROST 1/32 ICE UNDERCOAT	96	135	
109	29.88	72		96%		1/2" FROST 1/32 ICE UNDERCOAT	96	135	
112	30.127	75.6		53%		1/2" FROST 1/32 ICE UNDERCOAT	96	135	
114	29.97	55.0		25%	CLEAR	3/8" FROST	14	20	SCRAPED 1 SQ. FT. FROM TANK AND WEIGHTED DENSITY = 0.036 LBS/FT^2
114	29.98	59		43%	CLEAR	1/4" FROST ICE	9	13	SCRAPED 1 SQ. FT. FROM TANK AND WEIGHTED DENSITY = 0.022 LB/FT^2
116	30.07	68		70%	CLEAR & SUNNY	1/4" FROST	9	13	ACTUAL DENSITY = 0.222 LB/FT^2
118	30.18	87.2		65%	HOT & CLEAR	1/2" FROST	18	25	ACTUAL DENSITY = 0.026 LB/FT^2
120	29.875	60.7		96%	CLOUDY	3/8" FROST	14	20	
127	29.865	76.1		91%	CLEAR	5/16" FROST	12	16	
131	29.805	71		81%	CLOUDY & OVER-CAST	1/4" FROST	9	13	
133	30.120	76.0		66%	CLEAR & WARM	1/4" FROST	9	13	
135	30.035	80		79%	OVERCAST, RAIN-ING & WARM	1/4" ICE	629	888	INDICATES RAINING
136	29.905	71		98%	CLOUDY & WARM	1/4" ICE	629	888	RECORDS INDICATE ICE BUT PROBABLY FROST
202	30.07	74		100%	WARM, CLEAR SKY	≈3/8" ICE	944	1332	
187	30.14	78	≈ 10 MPH	86%	WARM, SUNNY	1/4" FROST	9	13	
176	29.81	80		57%	SUNNY, WARM	1/4" FROST	9	13	
164	30.07	71	0–10 MPH	58%	CLEAR, SUNNY, WARM	1/4" FROST	9	13	
146	30.17	65.7		62%	CLOUDY, WINDY, COOL	1/4" FROST	9	13	

THE ABOVE DATA WAS OBTAINED FROM "WEIGHT DATA BOOKS." THE DATA IN THESE BOOKS WERE RECORDED AT THE TIME OF LAUNCH AND RETURNED TO SANTA MONICA FOR POST FLIGHT EVALUATION. DATA ON BOOSTERS 104 THROUGH 120 IS CONSIDERED GOOD.

WEIGHT ANALYSIS SECTION
31 MARCH 1971

SOURCE: MDAC-W

FIGURE 2

PASSIVE ICE PROTECTION SYSTEM

(REFERENCE: DOUGLAS PAPER 5102. "ICING TUNNEL TESTS OF ICEPHOBIC COATINGS," DATED SEPT. 1968)

SURFACE	MEAN SHEAR STRESSES	SHEAR STRESS REDUCTION
UNCOATED ALUMINUM	20.04 ± 5.54 PSI	0
3M, EC-1981	14.02 ± 4.19	6 PSI
DUPONT, 954-101 (TEFLON)	11.53 ± 0.49	8.5
DOW CORNING 92-009 (SILICON)	10.03 ± 2.44	10.0

SOURCE: MDAC-W

FIGURE 3

Subject: Further Comments - Hard Ice Formation on a Heat Sink Booster - Case 237

From: C. Bendersky

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